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Improvement of Steam Turbine Operational Performance and Reliability with using Modern Information Technologies

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Abstract. The report presents improvement methods review in the fields of the steam turbine units design and operation based on modern information technologies application. In accordance with the life cycle methodology support, a conceptual model of the information support system during life cycle main stages (LC) of steam turbine unit is suggested.

A classifying system, which ensures the creation of sustainable information links between the engineer team (manufacture's plant) and customer organizations (power plants), is proposed.

Within report, the principle of parameterization expansion beyond the geometric constructions at the design and improvement process of steam turbine unit equipment is proposed, studied and justified.

The report presents the steam turbine unit equipment design methodology based on the brand new oil-cooler design system that have been developed and implemented by authors. This design system combines the construction subsystem, which is characterized by extensive usage of family tables and templates, and computation subsystem, which includes a methodology for the thermal-hydraulic zone-by-zone oil coolers design calculations.

The report presents data about the developed software for operational monitoring, assessment of equipment parameters features as well as its implementation on five power plants.

1. Introduction

The state of the art feature concerned to the design process of steam turbines is the transition from typical to custom design and manufacturing of steam turbines and steam turbine units (hereinafter - STU). The share of unique projects concerned to the construction of new power plants and modernization of existing ones in the basket of orders of turbine plants (according to estimates of the leading designers of Ural Turbine Plant, hereinafter - UTZ) exceeds 90%. Among the remaining 10% of orders, 90% is for reconstruction or modernization. The complexity of the design in this case is the need to link the projected of STU with the existing building structures, the foundations of the power plant, and often the remaining elements of the equipment.

According to the data of [1], a significant part of the complaints, related to the design documentation and presented to the turbine manufacture engineers, refers to errors caused by the fault of the equipment supplier and / or by the mistakes which is made at the stage of the technical assignment formulation as well as by the errors made by the engineers while design schemes, equipment layouts or calculations processes within the pipeline scheme development.

In Figure 1 presented a histogram, which is constructed based on statistical analysis of the design documentation complaints [1].

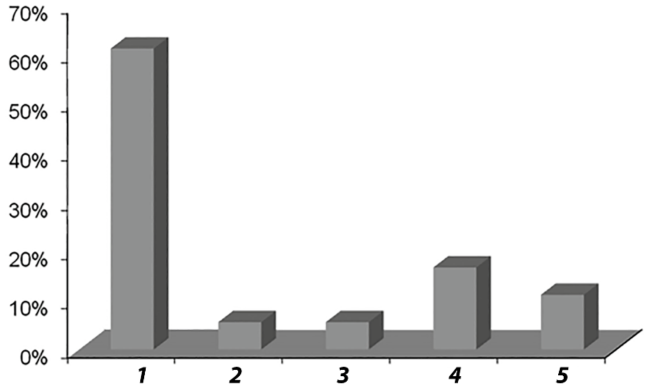

Figure 1. Distribution of complaints:
1 - errors in the STU layout design, 2 - circuit errors,
3 - errors in the calculations, 4 - vendor errors,
5 - mistakes in the pipeline's scheme development

The reason for a significant part of the complaints, as can be seen from the figure, are the errors that occurred at the stage of the STU layout design (up to 65% of all complaints). Among the mistakes within the STU layout design, the errors associated with collisions (non-projected intersections) arising during the design of pipeline schemes take the first place, followed by errors that occur during the arrangement of equipment and, last but not least, errors that occur in the design of building structures.

Elimination of the consequences of such errors is carried out during the installation process, which increases its deadlines and reduces the reliability of the equipment of the steam turbine plant. Thus, the improvement of the layout design system of the technical equipment improves the reliability and manufacturability of equipment and reduces the cost of commissioning the equipment.

The key features concerned to design process of STU is the continuous interaction of the departments of the design bureau (DB) throughout the entire design process. Numerous refinements and approvals create a large number of iterations. The transfer of information from departments to departments is carried out both with the help of paper carriers, and in various formats of electronic representation. The urgency of the information is maintained as a result of repeated inspections in all departments of the Design Bureau. Often, the same source information is entered several times. The data for carrying out numerous calculations are manually entered, which is fraught with the risk of making mistakes. Sometimes interpretation of the results of calculations allows for an ambiguous interpretation, which leads to errors in the project. Accompanying operational documentation, taking into account the presence of numerous iterations in the design process, does not always correspond to the final results presented in the design documentation. Consequently, the technology that being used through the STU design and their layouts contains reserves for improvement as well as the information links between departments in the design process do not meet modern requirements. Modern information technologies provide an opportunity to solve many of the problems identified.

2. Development of a classifiers system for units and parts of STU equipment.

As a tool for increasing the efficiency and reliability of the STU while operation, the authors selected a complex of technologies for continuous information support of products (CALS-technologies). To provide information support for the equipment at various stages of its life cycle, it is necessary to perform a design analysis, an analysis of the structure of equipment elements, and assign unique codes to them. Analysis of the existing systems of classification and coding of units and parts, equipment of the vocational school has shown that none of the existing classifiers can fully meet the requirements of information support at all stages of the LC of elements of steam turbine installations. The solution of the problem of codification lies in the creation of a system of classifiers, which is the integration of the most suitable and finalized classifiers at various stages of STU life cycle. In order to provide information support for the STU equipment in the production and post-production life cycle stages, the authors proposed a system of classifiers. That system is an integration of the S1000D classifier [2] accepted as a standard in the USA and the European Union, as well as the international classifiers AKS and KKS [3, 4] that were previously used in Russia and modernized by the authors. The encodings AKS and KKS [3, 4], used in the USSR and in Russia in the development of APCS, do not provide uniqueness of the code, which can lead to the assignment of the same code to different elements of the circuit. This deficiency is deprived of the modified AKS codifier. However, in case of manual codification, the problem related to the possibility of differences in the coding of the elements of the technological scheme performed by different specialists and / or at different times remains. To solve this problem, the author developed a software module that provides automated codification of technical objects at the power plant and technological parameters based on the modified AKS codifier. The use of this module eliminates the heterogeneous codification of the same technological parameters.

A similar modification was also made with respect to the codifier KKS [4], since KKS is also used extensively in power plants. The software module for automated codification has been finalized, and in Figure 2 shows, for example, a dialog box of a working module in which the codification of process parameters is made simultaneously in the AKS and KKS encodings.

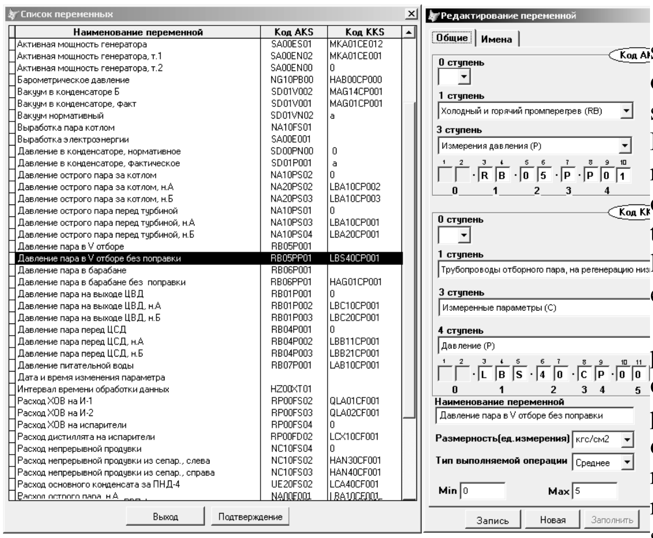

Figure 2. Dialog box of the software module for automated coding of the power station equipment’s technological elements

The experience of applying the described software module inside proper software for operation analysis of the STU equipment showed that the modified coders AKS and KKS provide sufficient capacity and the necessary completeness that guarantee the coverage of technical objects and technological parameters within the required limits of the analysis of operation STU equipment.

Operation experience in various power plants has shown that other requirements for codifiers are met: justified depth; the possibility of solving a complex of tasks at different levels; the possibility of expanding a number of classified objects and making the necessary changes in the classification structure; ensuring the possibility of interfacing with other classifications of homogeneous objects; ensuring the ease of keeping the classifier.

3. Expansion of parametrization using the example of the design of oil coolers

The design of steam turbine equipment at the turbine plant is an iterative process in which the calculation procedures alternate with the design ones, and often the data for the calculations are manually entered, which is fraught with the risk of making mistakes. The design system developed with the participation of the authors for the oil coolers design is largely insured against such errors, since it is based on the integration of the design subsystem with the extensive use of tables of families and templates and a calculation subsystem that includes the refined methodology of the zonal thermal-hydraulic calculation of oil coolers of steam turbines. The projecting subsystem that provides solid 3D modeling in the Creo Parametric environment and the computational models are integrated into a single design and design system. In Figure 3, a 3D model of the modernized oil cooler designed by UrFU is presented as an example. Oil coolers of this type are manufactured and successfully operate in dozens of power plants in Russia.

4. Increasing the efficiency and reliability of the STU equipment while operation

The analysis of the operation of the STU equipment, increasing the efficiency and reliability of its work is unthinkable today without the use of modern information technologies. With the participation of the authors, the in-house "Operation" software was developed and implemented at five power plants in Russia. The complex includes such tasks as "Calculation of technical and economic indicators (TEI)", "Calculation of TEI for the single interval" and "Monitoring of equipment status".

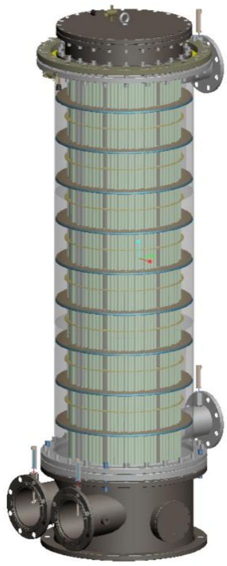

Figure 3. 3D-model of the modernized oil cooler designed by UrFU

This software is designed to solve the post-operational monitoring tasks of the power plant equipment. The most important task of rational and economical management of the power plant is the selection of the optimal composition and loads of the power generating equipment. The optimization criterion for the distribution of loads is the minimum of the total consumption of heat (fuel) for energy production. The solution of the problem of optimization of load sharing between power units, based on the use of the regulatory characteristics of fuel consumption is not enough accurate, in the opinion of the authors. While the operation the equipment wears out as well as during the repairs and reconstruction the equipment elements are replaced and, as a result, the basement characteristic of the power unit does not fully correspond to its real state. "Monitoring of the state of equipment", working as part of a software package at the power plant, provides updated information on the status of the equipment of the steam turbine plant, the real parameters and capabilities of the equipment in operation.

To date, with the participation of the authors, work is underway to re-engineer the software platform for the Operation Complex and finalize the calculation modules for optimizing load distribution and evaluating the start-up of Surgutskaya GRES-1 power units.

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